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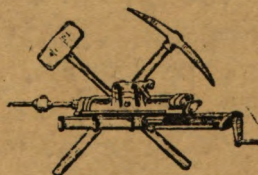
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THE PAHASAPA QUARTERLY

SIoux INDIAN: "PAHA," HILLS "SAPA" BLACK.



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A DEER TRAIL IN THE BLACK HILLS.

THE PAHASAPA QUARTERLY

SIoux INDIAN: "PAHA," HILLS "SAPA" BLACK

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No. 3

BACTERIA AND IRON DEPOSITION¹

By E. C. HARDER

The following discussion is a brief summary of present knowledge regarding the transportation and deposition of iron compounds in surface waters. Much of the material is drawn from the extensive literature on the subject; some is the result of my own recent investigations relating to iron-depositing bacteria.²

The precipitation of iron compounds from surface waters has generally been ascribed mainly to chemical action, the deposition occurring either through oxidation and hydrolysis, in which case limonite or related hydroxides are deposited or through reaction with other compounds in solution, in which case iron carbonate, iron silicate, or iron sulphide may be deposited. It has been known for a long time, that organisms also are actively concerned in the formation of deposits of ferric hydroxide and iron sulphide, but the importance that they merit has not been accorded to them. It seems probable that the deposition of iron as ferric hydroxide is by far the most important and that even where the iron is found as carbonate, which is common, the change has generally occurred after precipitation, due to decaying organic matter or other deoxidizing

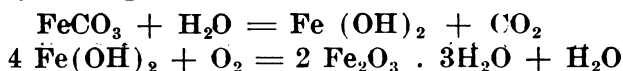
¹ Published by permission of the Director, U. S. Geological Survey.

² Harder, E. C., Iron-depositing bacteria and their geologic relations: U. S. Geol. Survey Prof. Paper 113, 1919.

agents. Iron silicate and iron sulphide are of minor importance as sedimentary deposits.

There is good reason to believe that iron is carried in solution in surface waters mostly as the soluble carbonate (or bicarbonate). Small amounts may locally be carried as sulphate, and it is believed that some may be present in the form of organic compounds. Soluble iron carbonate may be transported in solution in surface waters for an indefinite length of time and in considerable quantity as long as the waters carrying it contain an excess of carbon dioxide in the free state. When the waters become depleted of carbon dioxide, however, precipitation of the iron may take place either as ferric silicate or iron sulphide depending on the conditions under which deposition occurs.

Ferric hydroxide is the most common form in which iron is precipitated from solution in surface waters. It forms when iron-bearing waters, upon losing their carbon dioxide, become saturated with oxygen. The following reactions express what probably takes place:



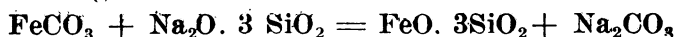
The precipitate is flocculent, yellow, ochreous limonite which is common wherever iron-bearing water issues from rocks or soil. It is in the formation of this flocculent deposit of ferric hydroxide that iron-depositing bacteria are active agents. I have examined ochreous scums from many places and almost invariably have found that they are largely and frequently almost entirely made up of bacterial remains. This is an indication of the importance of such organisms in iron deposition. By the accumulation of these ochreous iron scums bog or lake limonite deposits are gradually formed. To what degree such accumulations enter into the formation of more extensive sedimentary beds of limonite and hematite is problematic, however. Iron-depositing bacteria up to the present have not been found in salt waters and as many of the bedded iron ores contain salt water fossils their deposition through

the agency of ordinary iron bacteria cannot be strongly argued. However, it is not impossible that flocculent iron bacterial scum may be formed in the lower courses of streams and carried in suspension to brackish or salt water lagoons.

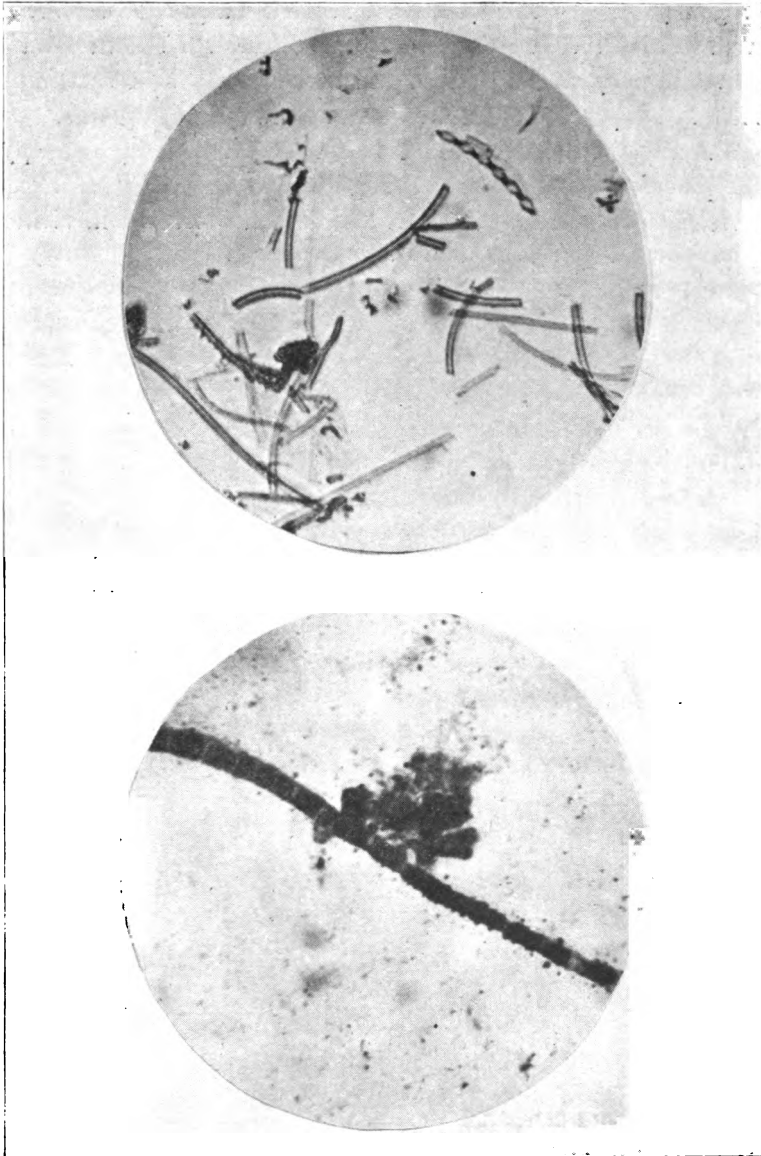
When flocculent limonite scum is formed in swampy or boggy places it may upon settling become mixed with decaying organic matter and suffer deoxidation and conversion, either altogether or in part, to ferrous carbonate. Sedimentary iron carbonate beds formed under such conditions are of common occurrence in modern bogs, and it seems quite probable that the special variety of carbonate ore known as black band ore and the related clay band or flag ores associated with coal beds were formed in this manner.

It is believed by some investigators that ferrous carbonate may be precipitated directly from solutions of soluble ferrous carbonate without the intermediate formation of ferric hydroxide. This is believed to take place when solutions become depleted of free carbon dioxide under conditions which do not allow its replacement by oxygen. How such conditions can obtain any important degree at the surface is somewhat difficult to conceive, however.

Iron silicate may be deposited from solutions of ferrous carbonate by interaction with alkaline silicates as is indicated by the following reaction:



The precipitate of ferrous silicate is light green and flocculent and has a tendency to develop a granular texture upon standing. Granular or oolitic sedimentary beds of iron silicate are of common occurrence in widely separated areas. In places, as in Newfoundland, iron silicate and oolitic hematite are intermixed in the same beds. Oolitic iron carbonate and limonite may also occur under such conditions, as in northern France. It is believed that in the presence of excess carbon dioxide in solution ferrous silicate may be decomposed and subsequently changed to ferrous carbonate. Organisms are not known to be concerned in the deposition of iron silicate.



TYPE OF IRON-DEPOSITING BACTERIA (Magnification 570).

The precipitation of ferrous sulphide from waters containing soluble iron carbonate is of extremely common occurrence. The precipitation results from the action of hydrogen sulphide on the iron salt in solution as follows:



It is very probable that this reaction would be resisted by the loss of carbon dioxide from the solution, although it is not certain that such loss would be absolutely essential. The hydrogen sulphide is formed mainly by the decaying action of putrefying bacteria on sulphur-bearing proteins. Black ferrous sulphide muds are being formed at the present time in the Black Sea and elsewhere. It is believed that the ferrous sulphide gradually changes to iron disulphide and that in this manner many beds of oolitic or massive pyrite interlayered with sedimentary rocks may be accounted for. The fact that carbonaceous matter is generally associated with pyrite in sedimentary rocks strengthens this hypothesis.

The preceding discussion shows how various stable iron compounds may be precipitated under various conditions from waters containing soluble ferrous carbonate. In the same way it may be shown that such compounds are precipitated also from solutions of iron sulphate or organic iron compounds, but these are probably of minor importance in surface iron-bearing waters.

Ferric hydroxide is precipitated from solutions of iron sulphate by the action of alkalis, by hydrolysis, or in the case of ferrous sulphate, by combined oxidation and hydrolysis. Generally in these reactions varying amounts of basic ferric sulphates are formed as intermediate products, but the final product is ferric hydroxide.

Ferrous silicate may be formed from ferrous sulphate by reaction with alkaline silicates analogous to its formation from ferrous carbonate in solution. Ferrous carbonate may form from ferrous silicate in the presence of excess carbon dioxide as already mentioned.

Ferrous sulphide may be precipitated from iron sulphate

solutions by the action of sulphate-reducing bacteria. These bacteria constitute a group of organisms that have the power, in the presence of decaying organic matter, of reducing sulphates, sulphides, and thio-sulphates in solution to sulphides.

Nothing definite is known of the occurrence of iron salts of organic acids in surface water, but there are numerous references in the literature to the presence of such salts in which they are usually designated by the rather indefinite terms of ferrohumes, salts of the complex humic acids formed during the decomposition of humus. In addition it is possible that certain well known organic acids such as citric, malic, butyric, acetic, tartaric, and their salts occur in surface waters and soil to a greater extent than is generally believed.

From solutions of iron salts of some of these acids such as acetates, lactates, oxalates, and others, basic ferric compounds analogous to basic ferric sulphate are readily precipitated by alkalies or by hydrolysis. These compounds change gradually to ferric hydroxide. In solutions of iron salts of others, however, including humates, citrates, and tartrates, basic ferric salts or ferric hydroxide do not readily precipitate because the iron in them forms part of an "inner complex salt." Such iron compounds may, therefore, be retained in solution for an indefinite length of time. Certain bacteria, however, attack these salts and cause the precipitation of ferric hydroxide from them.

From the preceding discussion it is evident that bacteria play an important part in the deposition of iron compounds. Some of them, such as the iron-depositing bacteria proper, attack directly iron salts in solution and cause precipitates to form, others act only indirectly by producing compounds which attack iron salts in solution and cause their precipitation. Certain of the iron-depositing bacteria are active agents in the deposition of ferric hydroxide from iron carbonate solutions and from solutions of organic iron salts; these deposit ferrous sulphide by the reduction of the sulphate. The bacteria which are indirectly concerned in the formation of iron compounds are mainly the decay-producing bacteria. These organisms are responsible for the reduction of ferric hydroxide to iron carbon-

ate and for the production of hydrogen sulphide which attacks ferrous carbonate in solution causing the precipitation of ferrous sulphide. Thus the only one of the iron compounds discussed in the formation of which bacteria are not known to be concerned is iron silicate.

The most common as well as the most important of the iron-depositing bacteria are those which deposit ferric hydroxide. They are commonly known as "iron bacteria." Until within about the last ten years all the ferric hydroxide-depositing bacteria known belonged to the class called thread bacteria, long thread-like organisms, some cylindrical with cells placed end to end and plainly visible; others ribbon-like, spirally twisted forms without apparent cell structure. More recently, however, certain lower bacteria, both bacilli and cocci, have been found which precipitate ferric hydroxide. Some of these deposit ferric hydroxide from natural iron carbonate-bearing waters; others precipitate it from solutions of organic iron salts. The latter are the most recently discovered ones.

There has been much discussion regarding the physiological significance of the deposition of ferric hydroxide from iron carbonate solutions by organisms. Some investigators maintain that the precipitation is purely a chemical process and that the iron-depositing organisms are merely concerned in collecting on their mucilaginous coverings ferric hydroxide which is formed by simple oxidation and hydrolysis. Others state that the action is a part of the life process of the organisms; that the latter use the carbon dioxide liberated for food and that the oxidation to ferric hydroxide furnishes energy. In part this difference of opinion is due to the fact that different investigators have been working with different organisms; in part, however, it is due to faulty observation.

Experiments up to the present have shown that ferric hydroxide-depositing bacteria may be grouped into three principal types as regards physiological activities: (1) Those which precipitate ferric hydroxide from solutions of ferrous carbonate and use the carbon dioxide liberated and the energy produced during oxidation for their life processes. They require

ferrous carbonate and cannot exist without it. Certain iron-depositing thread bacteria belong to this group. (2) Those which do not require ferrous carbonate in solution for their life processes, but which cause the deposition and accumulation of ferric hydroxide when iron salts are present. They precipitate iron from either inorganic or organic iron salts. This class also includes certain thread bacteria and probably some lower bacteria. (3) Those which attack organic iron salts probably using the organic acid radical as food and precipitating ferric hydroxide. These organisms cannot utilize inorganic iron salts. They include many lower bacteria.

In the above article, Mr. Harder has described certain chemical and biological activities that seem to give a hint as to the manner of deposition of the many bog-limonite deposits along the western side of the metamorphic area of the Black Hills, particularly west of the Chicago, Burlington and Quincy Railroad in the vicinity of Rochford, Hill City, Custer and elsewhere. Those deposits northwest of Rochford have been mined to some extent and used in the manufacture of paint.

What is declared to be one of the richest gold discoveries in the Dominion, was recently made by an Indian prospector, Jacob Cook, at a place seventy miles north of The Pas, Manitoba, and east of the Flin Flon copper mine. Pound chunks of quartz, half gold, in string and leaf form, are reported. The vein is six feet wide and outcrops for more than a mile.

One of the richest gold pockets which has been found on the continent occurred in the Croesus Mine, in Northern Ontario, where a yield of about \$85,000 per ton was obtained. Six examples of this ore, valued at \$10,000, were purchased by the Ontario government.

A Swedish scientist has produced a flame with a higher temperature than that of oxyacetylene and has also devised a burner employing powdered aluminum and oxygen.

NOTES ON WATER SOFTENING.

W. J. SHARWOOD.

Pure water is practically unknown in nature; even rain water contains dissolved gases from the atmosphere, in addition to such materials as may be taken up during collection and storage. It is however always "soft," lathering freely on the first addition of soap. Water flowing from granite areas is often nearly as pure as rain water. Water from most streams, wells and other sources contains more or less dissolved inorganic salts of various kinds, which are carried on to the ocean, where some of them accumulate. Most common among these are the carbonates (or bicarbonates), sulphates and chlorides, of calcium, magnesium and sodium. Silica and compounds of iron and potassium are sometimes found in considerable quantity, and free hydrogen sulphide, carbon dioxide, and sulphuric acid.

Between the Sierra Nevada and the Mississippi natural waters are found containing almost every conceivable mixture of these compounds. Analyses of many types are tabulated in F. W. Clarke's *Data of Geo-chemistry*.

In the Northern Black Hills streams flowing from the limestone carry bicarbonates of calcium and magnesium, while water issuing from mines and openings in pyritic schists may contain quite large properties of sulphates of those metals and of iron. Chlorides are found here only in traces, unless the supply has been contaminated. Some of the well waters also carry a considerable amount of sulphate.

In engineering work and manufacturing the mineral constituents are of great importance. For instance, tanneries and breweries demand water of a particular kind, and some important industries have been localized for such reasons. On the other hand, steam power plants, and also locomotives and steamships, commonly have to take such water as is most readily available, and engineers must then deal with it as best they can.

Simple percolation through beds of sand removes suspended clay and also most of the organisms that may be present, and the latter may also be destroyed by adding even minute amounts of chlorine, bleaching powder, or copper sulphate.

Some of the substances mentioned as occurring in natural

waters tend to corrode the iron or steel shells and tubes of boilers, while others are precipitated and form a scale, sometimes of great hardness; and, as the main functions of the metal are to withstand pressure and transmit heat, either of these conditions naturally leads to trouble. A thick scale not merely retards heat-transmission, but may cause dangerous local overheating and bulging of the walls or tubes of a high-pressure boiler.

Thus silica, the bicarbonates of calcium and magnesium, and calcium sulphate are all of the class known as incrusting solids. Sulphates and chlorides of the alkali-metals, chlorides of calcium and magnesium, and magnesium sulphate are all non-incrusting because soluble in water. Some of them have a tendency to cause foaming or priming in the boiler. They can be removed by "blowing-off" the boiler water at intervals before they become dangerously concentrated by evaporation. Some of these dissolved salts, especially the chlorides, tend to set up electrolysis and cause corrosion, and this tendency is increased by the presence of oxygen in the boiler. Oxygen and carbon dioxide together cause fairly rapid corrosion. The tendency to corrosion is diminished by the addition of a little dissolved sodium hydroxide or carbonate, or a small amount of lime. These must be used with caution, as sodium carbonate is gradually hydrolyzed to hydroxide, and this appears to be one cause of brittleness of steel, while the added lime forms more or less scale.

Marine boilers were formerly fed with sea-water, which was blown off at a certain stage of concentration, as determined by testing with the hydrometer. In more recent practice all feed-water is distilled, and bars of metallic zinc are introduced to protect the boiler shell electrolytically from the effect of such sodium chloride as may leak in through condensers, etc.

Calcium and magnesium compounds are commonly spoken of as making water "hard"; soap does not produce a lather until enough has been added to produce a curdy insoluble compound with these metals—a lime soap. The bicarbonates are said to cause "temporary hardness," as they can be removed for the most part by heating, carbon dioxide escaping and the normal

carbonate separating as a precipitate or scale. The sulphates and chlorides give a "permanent hardness" not removed by boiling. One of the earliest technical volumetric determinations was the use of soap solution in a burette to test water for hardness before and after boiling, the end-point being the formation of a lather on shaking. Calcium sulphate shows a remarkable solubility curve; it dissolves to about the same extent in cold and boiling water (about one in 500 parts), but at higher temperatures the solubility decreases rapidly; in steam boilers it is therefore almost entirely precipitated, forming a hard scale.

Many cures have been devised or suggested for scale in boilers. Very frequent blowing off removes loose precipitate, but is wasteful of fuel. Another plan is to introduce something to prevent the formation of hard crystalline scale, producing instead an easily removable powder or a soft mushy mass. Various substances have been used; among those recommended may be mentioned such things as a peck or two of potatoes, a bundle of twigs or hay, the carcass of a dog or a small pig put into the boiler once in a while, or a little glue, kerosene or oil added daily. Some of these empirical remedies were not entirely without merit, as colloidal substances tend to prevent the formation of hard crystalline precipitates, and to make the insoluble calcium sulphate or carbonate separate in a finely divided form, in which it could be more easily eliminated by blowing off. The same end has been attained by the addition of certain chemicals; sodium phosphate, fluoride, or aluminate, barium hydroxide or chloride, sodium carbonate alone or mixed with other compounds, have all been recommended and have been used with more or less success with certain waters. In most cases they should be added in amounts sufficient only to precipitate a small portion of the lime or magnesia present, this forming a nucleus on which the remainder would tend to precipitate later, rather than on the boiler shell.

The condition of the scale, when a boiler is opened for cleaning, depends to some extent on the manner of cooling it. If emptied soon after drawing the fires, the heat of the brick setting bakes and hardens the scale. If, after drawing the fire, the boiler is kept filled with water and allowed to cool gradually,

the scale is kept in the most favorable condition for removal.

When properly selected with due regard to the composition of the scale-forming ingredients of the water, such compounds have been used beneficially in many cases; they are usually dissolved and added to the feed-water. Much harm has however been done by unscrupulous people, who have sold cheap chemicals—often quite unsuitable for the particular water in use—at fancy prices to steam users. Organic materials, heavy oils, etc., used in this way may become sources of danger by forming thick soapy accumulations, and should be used with the greatest caution. If possible, the scale-forming ingredients should be removed before they reach the boiler.

Pre-heating the water breaks up the bicarbonates as before mentioned, throwing down nearly all the lime as the normal carbonates and much of the magnesia. For instance, five minutes boiling of the water of Spearfish creek will remove about half of the solids. When such water is heated and passed through a drum or large pipe filled with pebbles the latter become coated and facilitate the crystallization of the precipitate. Also by using condensers and returning the condensed water to the boilers the amount of scale is much reduced. Such returned water, containing air and carbon dioxide, may have a decided corrosive action and require additional raw water to protect the metal near the point of inlet.

Where hard water is to be used in a large boiler plant it is undoubtedly best to install a system of purification or softening before sending it to other boilers. The reagents must, of course, be chosen to fit any particular case, and used in suitable quantities. Cream of lime (calcium oxide slaked to form the hydroxide) precipitates calcium from the bicarbonate, both the original and the added lime falling out as CaCO_3 ; much of the magnesia may be similarly precipitated by lime, but it separates mainly as the hydroxide. Calcium sulphate requires the addition of sodium hydroxide and lime, or lime and soda ash (Na_2CO_3) may be added together; sodium sulphate then remains in solution.

This is a very old idea, the "Clark process" having been in use since 1830, but many and various forms of apparatus have

been used in its application. The main idea has been to induce the carbonates to separate as rapidly as possible, and this has been done by agitating and warming the water, causing it to cascade over large aprons or metal plates, or to pass over baffle-plates or through filters of coarse pebbles, or to settle in large tanks, all of which required to be cleaned at intervals. Originally two or more tanks were used alternately; one being filled with water, the reagents were added and stirred, it was then allowed to settle and the clear water drawn off from the top by a swinging pipe or hose which had a float at the open end. The more modern plants use the same reagents, but have improved methods of adding them to the moving stream of water, in exact proportion to the volume used, which may vary greatly with the demands of the boilers. A simple method of feeding lime; etc., is to lead the raw water in a continuous stream to the bottom of a cone or deep narrow tank, which may contain a revolving stirrer. Once or twice an hour a suitable charge is weighed out and put into the cone, and the water gradually carries it off through a settling tank. Perfectly uniform apportionment of reagents is not easily attained, and more elaborate mechanical feeds have been devised.

THE HOMESTAKE WATER SUPPLY.

As a practical example of a local boiler water, which forms a troublesome scale but is fairly easy to treat, the Spearfish Creek supply may be cited, which is pumped to Lead by the Homestake Mining Company through a system of vitrified tile and iron pipe. A typical analysis of this would run:

Calcium carbonate, about150 parts per million
Magnesium carbonate 84 parts per million
Silica 12 parts per million
Sodium chloride 5 parts per million
Sodium sulphate 2 parts per million
Iron oxide and alumina.....	3 parts per million
Suspended clayTrace
Organic matterMinute trace

Total solids left on evaporation 256 parts per million

It is practically neutral to phenol-phthalein, enough additional carbon dioxide being present to just keep the carbonates in solution; with methyl orange indicator 500 cc. of the above would consume 25 cc. of decinormal acid, so the alkalinity is equivalent to 250 parts CaCO_3 per million.

Formerly the Homestake had a number of scattered steam plants, each operating a single mill or a few units, with boilers of the horizontal return tube type; the largest installation was at the Ellison shaft, supplying the hoist, compressors and crushers. These have been gradually dismantled since the introduction of electric power, and the present Central Boiler Plant now operates only two hoists in addition to the two turbines which are auxiliary to the hydro-electric system. There are now six Edgemoor water-tube boilers, rated each at 500 HP., burning Wyoming coal on chain grates.

The old boilers, when fed with the above water, rapidly accumulated a hard scale, which entailed considerable labor in removing it from between the flues, etc. Various compounds were tried with more or less success, and conditions were much improved by the use of a mixture of soda ash with sodium phosphate (Na_3PO_4) or soda ash with sodium fluoride, added in small quantities to the feed-water. These cheap mixtures were more satisfactory than most of the high-priced compounds offered by sales agents. Either gave a deposit which was largely flocculent and could be blown off, while most of the remainder could be easily removed mechanically. In some cases, where a large proportion of the steam was condensed and returned, more or less corrosion took place in the heater, and the proportion of raw water was somewhat increased as a protection. This corrosion was due to carbon dioxide expelled from the bicarbonates or from the sodium carbonate by the boiler heat, and re-dissolved by the condensing steam.

On the installation of the Central Boiler Plant a purifying system was included. The water is easily softened by the Clark process, using lime only, and the type of apparatus selected was the Kennicott, the general arrangement of which is shown diagrammatically in Fig. 1.

The main Kennicott tank shown in the diagram is a cyl-

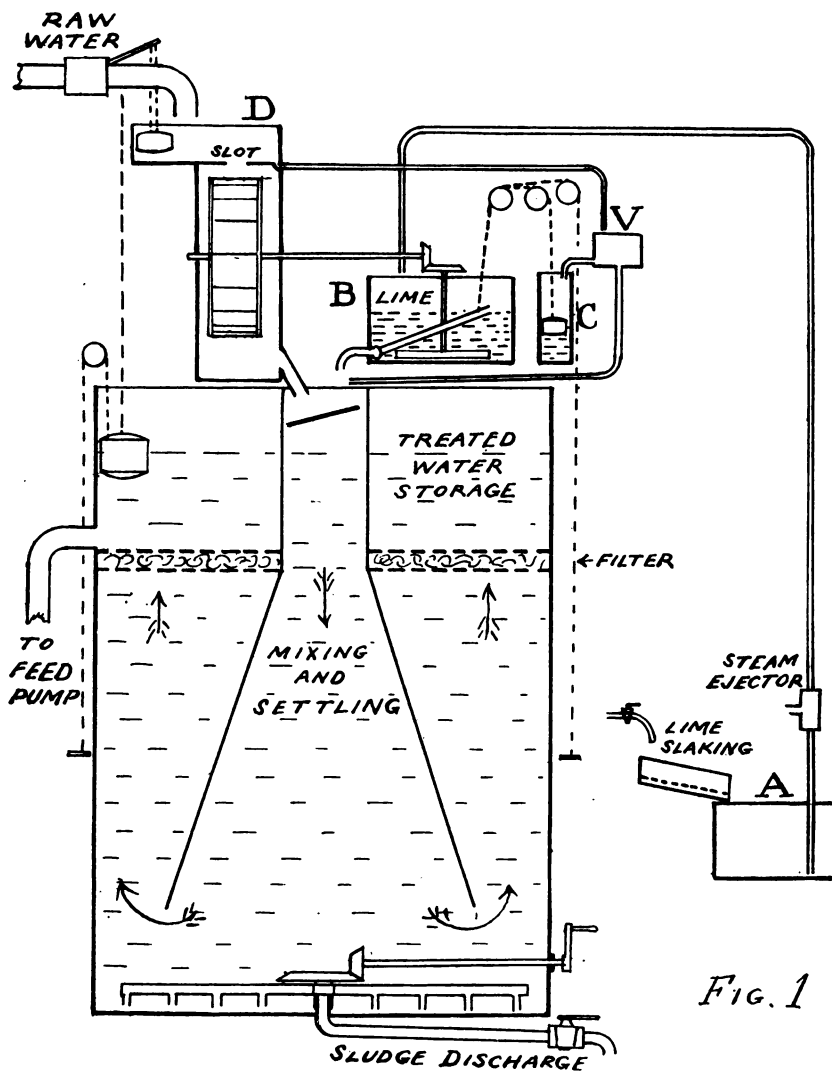


FIG. 1

Kennicott Apparatus for softening water by the Clark process.

inder of steel about 24 feet in diameter by 33 feet deep, in which is a central conical partition, extending nearly to the bottom, and surrounded, about 9 feet from the top, by a horizontal filter of excelsior confined between perforated steel plates. Raw water enters the top central opening together with the cream of lime and travels at a constantly reducing speed to the bottom and up again through the filter to the upper outside section of the tank which acts as a storage for the treated water. The precipitated material collects at the bottom, and is removed when necessary by the bottom valve. While this is open a radial pipe is slowly rotated by the handle shown, and draws off most of the deposited sludge by means of openings which pass over the bottom.

The mechanism for automatically apportioning the lime to the raw water is ingenious and effective. A charge of lime (usually 70 to 100 lb.) is slaked with hot water and passed through a screen into the tank A on the floor. It is then mixed with water and elevated by a steam ejector to the lime-tank B, which contains an agitator shaft and a swinging outlet pipe, hinged at the bottom. The upper end of this pipe is open, and is controlled by a chain attached to a float in a small tank or sump C alongside.

The raw water first enters a box D, at the bottom of which is a slot of adjustable width and also a small pipe. Most of the water goes through the slot and operates a water-wheel which drives the agitator in the lime-tank B. The smaller stream passes through a pipe to a "dividing valve" V, which diverts a small portion to the sump C containing the float. When the slot and dividing valve are once set the volume of water going to C is a small but constant fraction of the total water entering D. As this small stream flows into C the float rises, lowers the swinging pipe in the lime-tank B, and thus draws off a proportionate amount of the cream of lime which was made up to a fixed volume and is kept agitated by the wheel. This lime mixes with the main stream of water, striking a baffle plate and then falling into the central opening of the tank. The feed-pump draws its supply from the upper storage. If this becomes full a float rises and automatically closes the raw water inlet valve.

The same valve may also be closed by another float in the box D, which may be set to keep the head of water in this box at any desired height. Cords passing from floats in the storage and lime tanks indicate the levels of the liquids to the operator on the lower floor.

The length of time water takes to pass through this system may be computed. Taking the reaction chamber as a cylinder 24 by 24 feet, the capacity is 10,800 cubic feet. Suppose the consumption is such as to require continuous flow with the slot set at 5 by 1 inches and the head standing at 10 inches; the flow will then be roughly 13,500 cubic feet or about 100,000 gallons per 24 hours. The water therefore has, on the average, four-fifths of a day or 19 hours for precipitating and settling. With a larger consumption of raw water the time for settling is proportionately less.

This particular water, containing little beside carbonates, presents a very simple problem in purification, and the lime used costs less than a cent per thousand gallons treated. The extreme coldness of the water supply in winter somewhat reduces the capacity of the plant, as a rise of 10° or 15° F would appreciably hasten reaction and settling. If the water contained sulphates in quantity, like that of some creeks carrying mine drainage, it would be necessary to use soda ash in addition to the lime, or to add barium carbonate, and other waters could be dealt with by the use of suitable reagents in the same apparatus. The possible adjustments are: slot opening, head of water above slot, dividing-valve, and weight of reagent per charge; it is convenient to arrange these so that a charge lasts from 8 to 24 hours.

In treating such a water with lime the quantity must be carefully gauged. The importance of this is illustrated in Fig. 2, which shows the results of a series of laboratory tests with varying proportions of lime, ample time being allowed for complete reaction and filtering. Numerous points on the curves were obtained by titrating the alkalinity, and making analyses for lime and magnesium left in solution and thrown down as precipitates. The total alkalinity to methyl orange corresponds almost exactly to the sum of calcium and magnesium in solu-

tion. It is interesting to note that lime precipitates first (as carbonate) while magnesium barely begins to precipitate until the lime in solution has reached a minimum, and then falls out mainly as hydroxide. One molecule of calcium bicarbonate therefore requires one of lime to precipitate it, while one of magnesium bicarbonate requires two. In treating this particular water the point of highest efficiency is reached with the addition of about 400 to 450 parts of actual CaO per million, though some magnesia still remains in solution.

Samples are taken every four hours of the water going from the Kennicott to the boiler. A 500 cc. sample is titrated in a

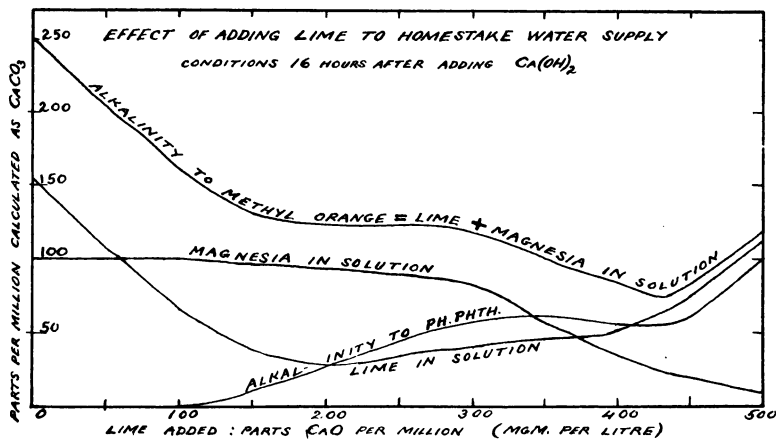


FIGURE 2.
Curves showing precipitation of Ca and Mg in H_2O by the addition of varying proportions of lime.

large basin with standard acid, using phenol-phthalein and methyl orange successively as indicators, noting each reading and their difference. One cc of tenth-normal acid, with methyl orange, means 5 milligrams of CaCO_3 in solution, or its equivalent (4.2 mgm.) of MgCO_3 ; for ordinary control work all the alkalinity is reckoned as CaCO_3 . Then, if 500 cc. uses 8 cc. of tenth-normal acid, (methyl orange indicator) the water contains the equivalent of 80 parts CaCO_3 per million, some of which is actually magnesia.

Sulphates can be neglected in this water. If necessary sulphate can be rapidly estimated by adding a little HCl to 100 cc. then a gram of barium chloride, shaking 5 minutes and observing the opacity with a candle turbidimeter or similar apparatus.

In actual daily work, under reasonably good conditions, this water can be purified to give about 56 and 80 with the two indicators, against 0 and 250 in the original water. Roughly this corresponds to about 5 and 15 grains of calcium carbonate per gallon in the treated and raw water, or the removal of approximately 70 per cent. of the scale-forming solids. Sixty per cent can be easily attained, or a titration of 100.

When the methyl orange titration is somewhat in excess of the minimum of about 80 it is sometimes difficult to decide whether this is due to addition of too much or too little lime. This may usually be guessed by noting the difference between the phenol-phthalein and methyl orange titrations, and comparing these with the alkalinity curves at the right-hand end of Fig. 2; it will be seen that these titrations approach more closely when lime is in excess. When a considerable excess of lime has been added it may be positively determined by a test with silver nitrate, which then gives a yellowish or light brown precipitate of silver oxide, instead of white carbonate.

PERMUTITE AND REFINITE.

The "Permutite" reaction is involved in a comparatively recent system of softening water. Some silicates, such as feldspars and zeolites, when powdered and moistened with water, render the water alkaline to indicators. Some zeolites also react with solutions of salts of copper, calcium, etc., exchanging these metals for the sodium of the silicates. In nature these reactions may take place on a very large scale; for instance, the sodium bicarbonate water met at a considerable depth in the Homestake mine is probably produced in this way by exchange with calcium and magnesium bicarbonates. In this connection it may be noted that the tendency is for mine waters found at greater depths to be more alkaline than those met comparatively near the surface; acid mine waters, and those containing sulphates of the heavy metals, usually belong to the latter class.

Permutite is an artificial silicate which may be made by fusing together one part kaolin, two of quartz, and four of soda ash (Na_2CO_3). Its composition would then approximate $\text{Al}_2\text{O}_3.10\text{Na}_2\text{O}.11\text{SiO}_2$. When a hard water is percolated through a large mass of crushed permutite the effluent water is nearly free from calcium and magnesium, having exchanged these metals for sodium. It is not purified in the strict sense but softened, and is then suitable for laundry purposes and in many cases for boiler use. The reaction is reversible, and the material gradually becomes saturated and inert. It may then be revived by treating it with a fairly strong solution of common salt, which removes most of the lime and magnesia as chlorides. It is claimed that this regeneration can be carried on repeatedly, but of course the amount of sodium chloride used each time will be at least equivalent to the quantity of calcium and magnesium previously removed from the water.

Near Ardmore, South Dakota, a similar material is now prepared directly from a natural silicate. A deposit of the mineral bentonite occurs here, which when baked, yields a material known by the trade name of "refinite." It is sold in a coarse granular form and has properties similar to those of permutite, and is now in successful use. For domestic use, for laundries, and for other operations on a moderate scale it promises to be of great value. It remains to be seen whether it can compete with the Clark process on the very large scale, as in important boiler installations.

The relative amounts of reagents used in the Clark and permutite processes may be easily compared. Suppose a water to contain the equivalent of 14 grains CaCO_3 (about 240 parts per million) held in solution as the bicarbonate, and that 50,000 gallons are used per day. This means just 100 lb. CaCO_3 to be removed daily. Theoretically this will require the addition of 56 lb. CaO , or about 60 lb. of the best quicklime. If the same water were softened by the permutite system the theoretical minimum of NaCl necessary to regenerate the permutite would be 117 lb., or say 120 lb. of good common salt.

A NEW FLOTATION MACHINE

Written for the Pahasapa Quarterly by A. W. FAHRENWALD.

A great variety of machines have been devised for the treatment of ores by what is known as the flotation process. By the flotation process metallurgists now understand that air-froth flotation is meant. "Film" or "skin" flotation processes are now obsolete as far as American practice is concerned. Hence, we are concerned entirely with methods of getting atmospheric air into intimate association with the mixture of mineral particles.

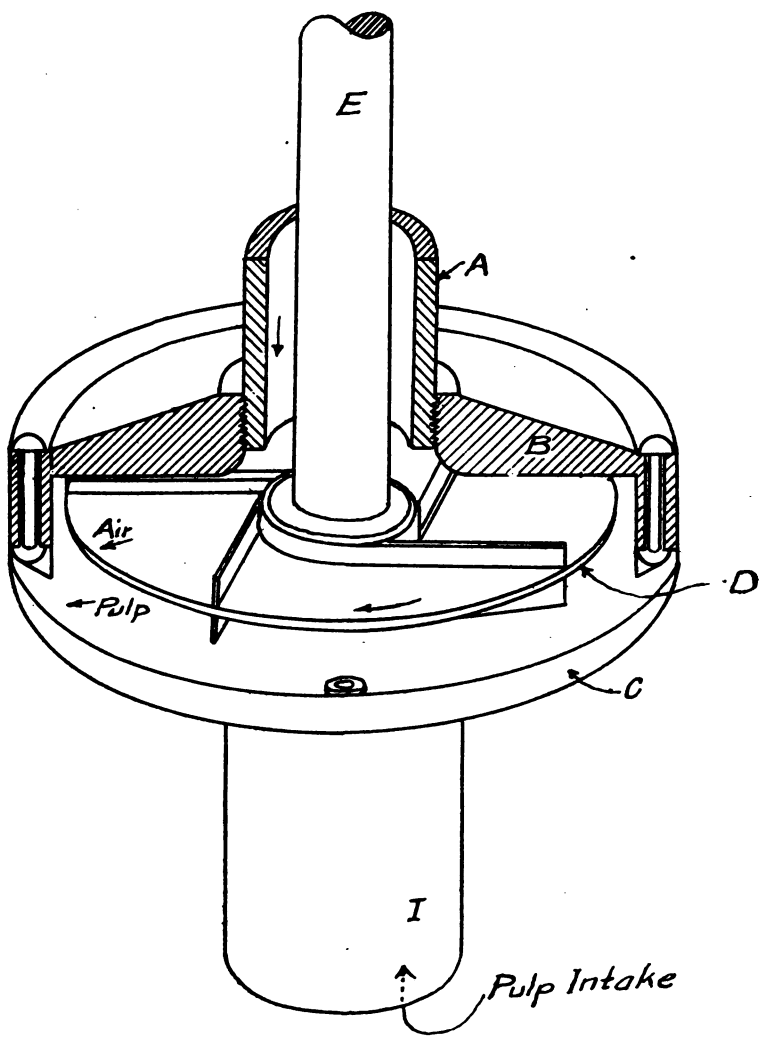
The important requirements of a flotation machine are that it shall efficiently and economically perform the following functions:

- (1) circulate the pulp perfectly,
- (2) aerate, and
- (3) agitate the pulp.

A flotation machine consists usually of a number of small units and the pulp passes through these in series. A perfect and positive circulation and passage from cell to cell must be had—this is not realized in many of the machines now in use and operating troubles, from the clogging of pipes and impellers due to the settling of heavy concentrates, are not infrequent in mills. This, of course, means a high cost per ton of ore treated. Therefore, first consideration, in the selection of a machine, should be given to this feature.

The next point of consideration, and of equal importance, is that of aeration. Machines employing violent agitation as a means of bringing about aeration of the pulp are anything but economical in their performance. The machine that will give the greatest aeration with a given amount of power is the machine that will demand consideration.

It is true that agitation of the pulp with oil is necessary in order that the oil will be thoroughly disseminated through the pulp and that the floatable particles will become thoroughly oiled, but in modern practice this is attained in the grinding mills. The oil is fed at the head of the mill with the ore feed and a far more thorough mixing of oil and ore-pulp is accomplished than can possibly be effected in the flotation cells. The



*Perspective showing principle of operation
Fig. 1*

dissemination of oil in ore-pulps in flotation cells is an extravagant and inefficient practice. The trend in flotation process is toward simplicity both of treatment and apparatus.

In the past few years the writer has devoted a great deal of time and thought to the development of devices for circulating and aerating pre-pulps both in cyanide and flotation practice. Recognizing the short-comings of pneumatic flotation devices particularly with reference to their porous bottoms through which air is forced and also appreciating the effect produced by such machines as the Ruth and Groch, an effort was made to develop a machine that would give efficient and controllable aeration without the use of porous bottoms—and necessarily air compressor devices—and perfect circulation of the pulp.

The device shown in the accompanying drawings is the result of this effort, a description of which follows:

The essential part of the machine is shown in Figure 1, which consists of a hollow tube or pipe A, from 1 to 5 inches in diameter (depending upon size of machine) extending down into the ore-pulp. At the lower extremity of the pipe there is attached two circular and parallel discs, B and C, C being held rigidly and at a fixed distance from B. Between the two discs revolves an impeller D receiving its rotation through shaft E, which operates in the pipe A; its bearings are also held rigidly in this pipe. Said impeller shaft E projects up through the pipe to take a pulley F, figure 3.

In pipe A is an opening G, controlled by a valve H, which, when the machine is in operation, constitutes the air (or other gas if the sulphidizing process for carbonate ores is used or if the Bradford SO_2 differential process is used) and oil intake. The passage of the air will be seen to be down the pipe A, where it is injected into the pulp with great force and in controllable quantities by the valve H. Simultaneously with this operation the impeller is circulating ore-pulp from the bottom of the cell through the pipe I, fastened into the lower disc C, and injecting it at its periphery with great force, causing an intimate contact of air and fresh pulp which travel in the same general direction.

The circulation and aeration of pulp is positive, and at all times under control, and the air can be regulated for the par-

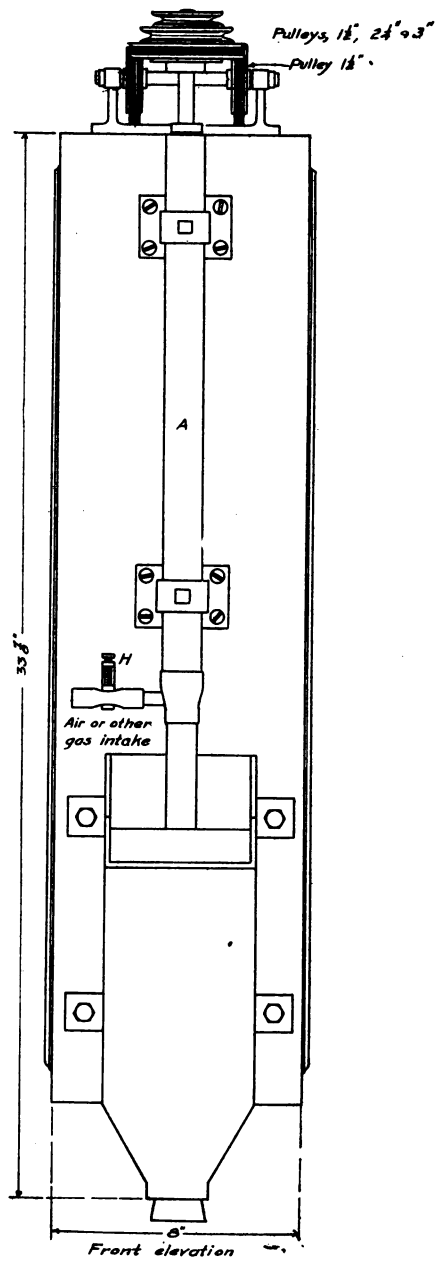


FIGURE 2.

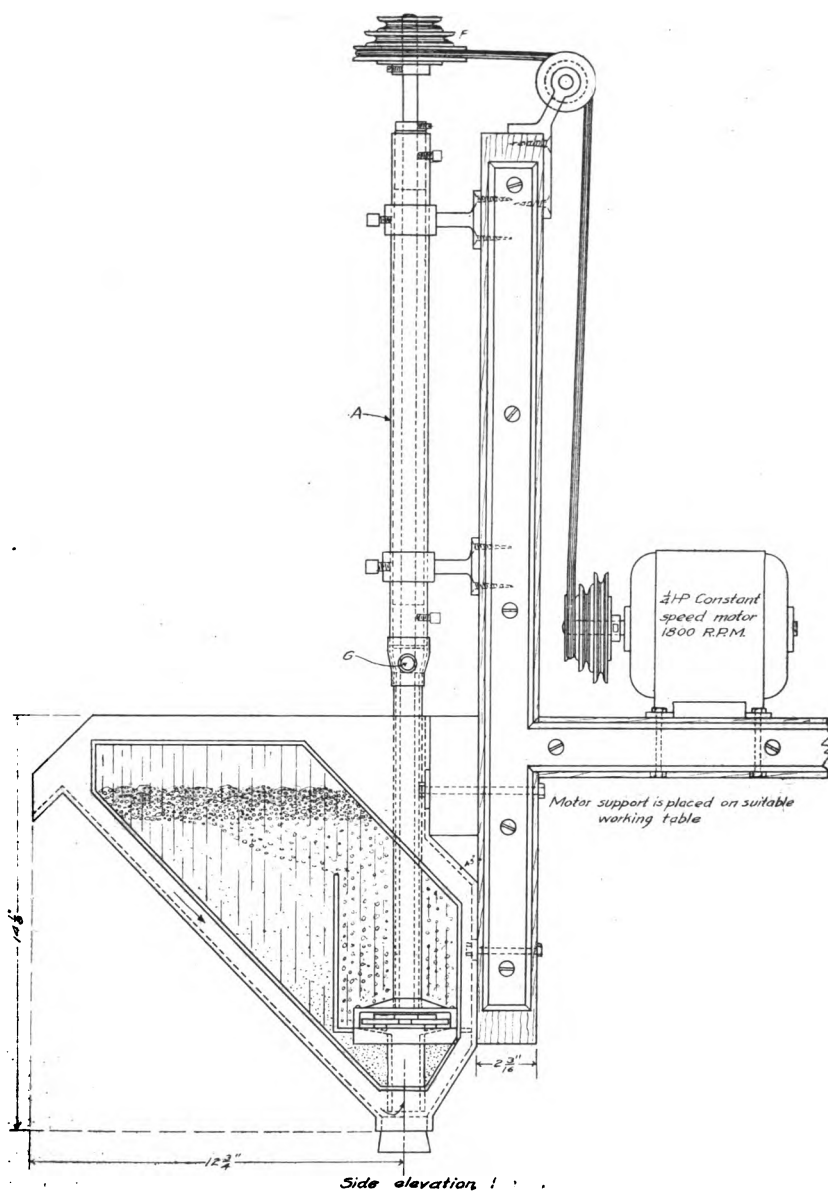


FIGURE 1.

ticular ore under treatment. Another important feature is that the device is its own air blower and that this air is injected into the pulp at a most advantageous point and condition, viz., at a considerable depth below the surface of the pulp in a highly dispersed condition.

The following are a few points of advantage claimed for this machine:

1. Efficient and controllable aeration .
2. Positive circulation of pulp.
3. New pulp receives new aeration, particles that sink are returned repeatedly to the action of aeration.
4. In case a gas is used for any purpose it is added more effectively and conveniently in this machine than in any other. Steam or atomized oil may also be added in this manner if they are used or required.
5. The principal part of the machine (pipe, impeller, and its shaft with bearings is a complete unit) is self-contained and replaceable at a minute's notice by having an extra one on hand.
6. A machine containing several of these aerators requires absolutely no drop from cell to cell which means small or minimum head-room and ease of operation.

In the operation of a laboratory machine of this design, enough water is added to bring the level just above the impeller. The impeller is put in motion by turning a switch to the motor, ore is then added. Agitation is allowed to continue for several minutes, oil and other reagents required to test are then added and the agitation and dissemination of these is allowed to continue for several more minutes depending upon the character of ore and oil used. The pulp level is then brought up to a suitable height by the addition of more water (usually within two or three inches of the overflow lip). The air valve, which has been closed, is now manipulated regulating the quantity of air injected into the pulp, and, consequently, the froth overflow. In a few minutes, depending upon the percentage of sulphides in the ore, the rich mineral concentrate will have all run off and the froth becomes clear. A cork is then removed from the bottom of the machine when the tailings are drained.

A VOLUMETRIC METHOD for the DETERMINATION OF TUNGSTEN IN ORES AND CONCENTRATES.

By GEORGE M. ENOS.

Those familiar with the usual gravimetric methods for the determination of tungsten, realize that not only is there much room for improvement in these methods, but that an accurate volumetric method would effect a great saving in time. Even a skilled analyst cannot complete an analysis of an ore by some gravimetric methods in much less than ten or fifteen hours. It was with the idea of finding a shorter and accurate method that this research was conducted.

Previous attempts to secure a suitable volumetric method have not been completely satisfactory. Scott¹ gives a method, using NaOH as the titrating solution, but does not recommend it. Knuht and Hibbart² give a volumetric method, using iron alum as the titrating solution and thiocyanate as an indicator. They refer to an earlier author, who had tried a permanganate method, but this reference was not available. No volumetric method is listed as a standard method as far as I was able to ascertain.

When tungstic oxide, WO_3 , is reduced by heating to dull redness in a current of hydrogen, WO_2 is formed, which can be still further reduced to metallic tungsten, if the temperature is raised. WO_2 is a brown powder, and when formed in the above manner is not stable in the presence of oxygen and must be cooled in a current of hydrogen.

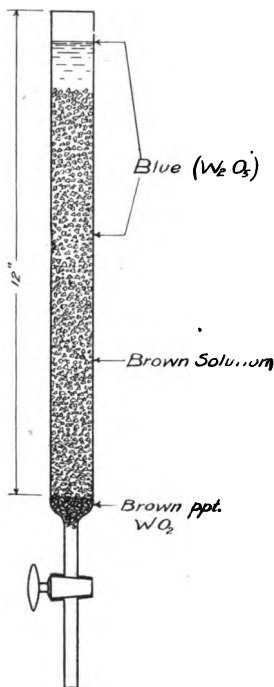
*Qualitative Detection of Tungsten*³—In minerals. Tungsten may ordinarily be detected in minerals by boiling the finely powdered material with concentrated hydrochloric acid until insoluble yellow tungstic acid is formed. Zinc or tin is then added and if tungsten is present in appreciable amounts, a blue color forms in the solution or the yellow residue turns blue, due to reduction by the nascent hydrogen." This is the usual qualita-

(1), (5) "Standard Methods of Chemical Analysis" (1) pp. 454; (5) 434 (1917),

(2) "Analyst," V. 36, p. 96.

(3) (6) Bulletin No. 12, SDSM, "The Occurrence, Chemistry, Metallurgy and Uses of Tungsten." (1918) by J. J. Runner and M. L. Hartman.

tive test. Reduction may be hastened by heating, if zinc be the metal used, the reduction may be continued until the brown WO_2 is formed. The blue color is believed to be due to the oxide W_2O_3 ⁴, or more probably to a mixture of WO_2 and WO_3 . The brown color of the solution is due to the presence of WO_2 in suspension, which will settle out if exposed to the air. It is probable that some of the WO_2 is reoxidized by air to WO_3 .



which is appreciably soluble in concentrated mineral acids, particularly HCl .

Experiments tried showed that zinc is probably the only common metal capable of reducing the WO_3 entirely to WO_2 . Aluminum, tin and stannous chloride in acid solutions were tried, but the reduction gave solutions which showed only the blue color, even after long continued boiling. Titrations tried on the blue solution produced by reduction with aluminum in acid solution, gave no checking results, indicating that a compound of

(4) 'Analytical Chemistry,' V. I, pp. 494 (1916).

definite composition was not present in the blue solution.

The general outline of the proposed volumetric method consists in acidifying a solution of an alkaline tungstate with sulphuric acid and the reduction of the tungsten from the hexavalent to the tetravalent state in acid solution by means of a Jones reducer, and finally oxidizing the tungsten to the hexavalent condition with a standard solution of potassium permanganate. This method has proved successful when certain precautions, which have been carefully worked out, are observed.

The accompanying cut of the Jones Reductor shows the action of the solution in the reductor, with the stages of reduction at different points indicated by the color changes. There is no reasonable doubt as to the completeness of the reduction.

OUTLINE OF THE PROCEDURE.

The tungsten is obtained in solution as an alkaline tungstate by any of the standard fusion methods. The removal of interfering elements may be accomplished by the methods given by Scott.⁵ It may be pointed out here that in the procedure given below, that Fe, Ca, Mg, and Mn will be removed by the filtration, and any copper or tin present will be precipitated on the zinc in the reductor.

The following method is satisfactory in most cases:

Fuse 2.5 grams of the finely powdered sample with 3.5 grams of Na_2CO_3 and .5 grams of KNO_3 for not less than one half hour, in either a platinum or a porcelain crucible. Dissolve the fused mass in hot water. Filter.

With some ores it may be advisable to make use of an alternative method of getting the material into solution, such as those of Ledoux and Company, A. H. Low, and J. A. Holliday. The first two are quoted in Bulletin No. 12,⁶ pp. 150-152. Where a large weight of sample is taken it is advisable to dilute the alkaline solution and take aliquot parts to be acidified and titrated.

Make the filtrate distinctly acid with H_2SO_4 and add 5-10 cc in excess. The solution at this point should not exceed 100 cc for best results. Heat to $80^\circ\text{--}90^\circ\text{C}$, and pass through the Jones reductor at a moderate rate. The reductor should be washed with dilute H_2SO_4 and the washings discarded before the solution

is passed through it. The solution above the zinc should show a deep blue color, and, when emerging from the zinc column, a deep brown color. Wash with 50-150 cc 2N-3N H_2SO_4 , being sure that all the brown precipitate of WO_2 is washed from the reductor. Finish washing with distilled water. Run the wash solutions into the same flask as the main solution. Titrate at once with .1N KMnO_4 .

The percentage of WO_3 can then be calculated from the following equation:

$$\frac{\text{cc KMnO}_4 \times \frac{232}{2}}{\text{wt. of sample}} \times N \times 100 = \% \text{WO}_3$$

In standardizing the procedure several determinations were made on WO_3 and Na_2WO_4 , but, owing to the indefinite composition of these materials, on which the method was first tried, and to other difficulties encountered, most of the preliminary runs did not check. Finally some pure WO_3 was prepared by dissolving some Merck's C. P. WO_3 in NH_4OH , precipitating with HNO_3 and drying, and then heating to about 500°C . This material was kept in an airtight bottle. The standardization of the procedure was then worked out on the oxide prepared in this way. The results are given in the following table.

Sample	W. by Vol. Method	W. Actual
Pure WO_3	80.02%	79.30%
Pure WO_3	77.8 %	79.30%
Pure WO_3	79.6 %	79.30%
Pure WO_3	79.5 %	79.30%

Several other determinations were carried out on different types of Tungsten ores and the results are compared with the gravimetric results obtained by Ledoux's ammonia method in the following table:

Sample	WO_3 by Vol. method	WO_3 (gravimetric)
Scheelite (1)	59.51%	59.60½
Scheelite (2)	79.9 %	76.67%
Tungsten Sands	2.8 %	2.8 %
Wolframite (1)	62.6 %	62.5 %
Wolframite (2)	20.41%	20.50%

Wolframite (3)	45.8 %	45.95%
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NOTES ON THE PROCEDURE.

Running dilute acid through the reductor first, produces an atmosphere of hydrogen, thus preventing oxidation of the tungsten in solution in the filter flask by the oxygen of the air. The flask should not be disconnected from the reductor until everything is in readiness to titrate.

The solution passing through the reductor must contain enough acid to liberate hydrogen freely. No harm results if the solution shows a slight turbidity.

The temperature of the solution should be about 80° C.

The reductor must be washed clear of WO_2 with dilute H_2SO_4 . The best results are obtained when 2N-3N H_2SO_4 is used.

The volume for titration should not exceed 300 cc and should not be cooler than 40°-50° c.

The end point in titrating is reached when the first permanent pink tinge appears. It is necessary to run a blank to determine the true end point, since it requires an appreciable amount of permanganate to produce a pink tinge in 200-300 cc of water acidulated with H_2SO_4 .

The entire run on an ordinary ore does not take longer than three hours.

This method does not need platinum dishes, as no difficulty is encountered by fusing in porcelain, and no long evaporations are necessary.

The tungsten solution may be run into an excess of ferric-sulphate where an equivalent amount of ferrous-sulphate is formed which may then be titrated with KMnO_4 .

It is also practical to run WO_2 into a measured quantity of KMnO_4 , the KMnO_4 being in excess. Titrate the excess permanganate with standard ferrous sulphate.

Scheelite No. 1 was a sample which had been checked by the Bureau of Standards.

The author wishes to express his thanks for the assistance given by Dr. Bisson and Dr. Traphagen of this school, and Dr. Hartman, of the Carborundum Co., Niagara Falls, N. Y.

A CONVENIENT HYDROGEN SULFID GENERATOR

By CHARLES S. BISSEON, Professor of Chemistry.

A generator for the production of small quantities of hydrogen sulfid, as well as other gases like carbon dioxide, hydrogen, etc., is a valuable piece of laboratory equipment. The generator described here operates on the principle of the Kipp Generator in which the concentration of the acid used gradually becomes smaller and smaller until it finally has no further action on the material in the generator.

It consists of a glass tube about 2 cm. in diameter and 17 cm. long with a bulb about 4.2 cm. in diameter blown with its center about 7 cm. from the sealed end of the tube shown in the

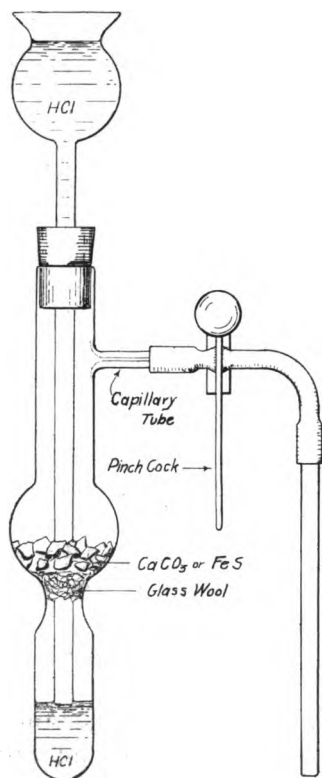


diagram. The tube is constricted to 8 mm. just below the bulb so as to allow the stem of an ordinary thistle tube, held in place at the top with a rubber stopper, to pass through with a clearance of about 1 mm. A capillary delivery tube attachment is sealed on about 8 cm. above the center of the bulb, and is of such length and diameter as to allow the gas to escape from the generator at the rate of about 2 to 3 bubbles per second, which is rapid enough for any ordinary gas precipitation process. This capillary may be substituted with a piece of ordinary 3 mm. glass tubing and the capillary tube placed in the rubber connection tubing just beyond the pinchcock, which simplifies its construction to a small extent. It is necessary for the successful operation of the generator that

the capillary tube be of such size as to allow a maximum rate of flow not greatly in excess of that specified.

In charging the generator the thistle tube is completely withdrawn, and the outer tube tilted on its side, and the bulb half filled with pieces, about 4 to 8 mesh, of iron sulfid, calcium carbonate, zinc, etc., depending on the gas to be generated. The thistle tube and stopper are then put in place. A finer material may be used by placing a thin layer of glass wool or asbestos around the stem of the thistle tube and dropping the fine material into the apparatus between the thistle tube and the outer glass tube. The rubber connection tube and pinch cock are then attached and the thistle tube filled with acid. While the generator is in operation the thistle tube, which serves as an acid reservoir, should be about one-fourth filled with acid, the difference in level of the liquid giving a good working gas pressure. The apparatus may be supported in a test tube rack or clasped to a ring stand and then connected with a small wash bottle if necessary. The apparatus requires but little material to operate it, and is easily cleansed.

A number of these generators have been constructed at the chemical laboratories of the South Dakota State School of Mines by the author, and have given very satisfactory results under working conditions in the laboratory. This apparatus constitutes a part of the regular desk equipment of the qualitative laboratory.

"The College Man" in "Colliers," written by Chas. S. Sabin, president of the Guaranty Trust Company, indicates the best way for a young man to spend his time during the years ordinarily devoted to a university training. The main idea brought out is the educating of engineers to be real thinkers.

So many students evince an interest in the mining operations of Mexico that their attention is directed to a series of articles entitled "The Ore Deposits of Mexico." The first of this series, written by S. J. Lewis, appears in the Mining and Scientific Press of March 20th, 1920.

A PECULIAR OCCURRENCE OF EPSOMITE IN THE BLACK HILLS.

W. A. WALDSCHMIDT, '20.

Epsomite, the natural Epsom salt, has to my knowledge never been described as occurring in the Black Hills. Recently however, epsomite has been found in two different localities in the Black Hills: one, the Homestake Mine at Lead, South Dakota; the other, the N. Pope Mine at Keystone, South Dakota.

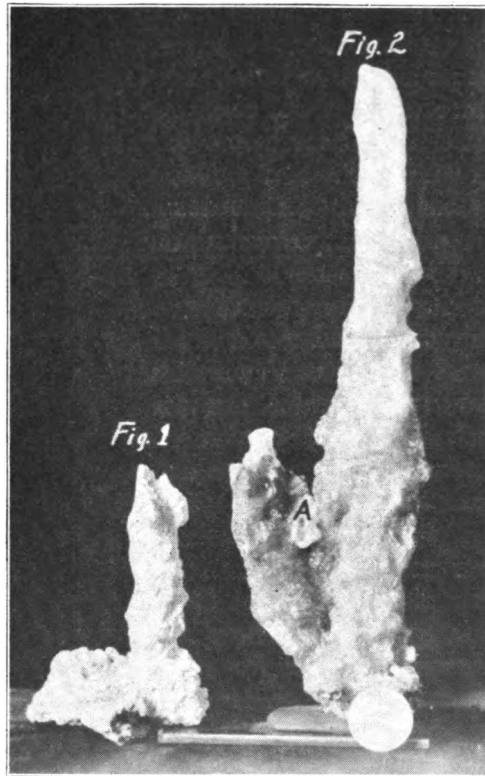
The accompanying photograph shows two stalactites of epsomite which were found in the Open Cut of the Homestake Mine. The stalactites were found attached to the timbers of an old, caved, timbered stope on the two hundred foot level which had been opened as the Open Cut mining advanced downward.

Epsomite is a hydrous magnesium sulphate, $\text{MgSO}_4 + 7\text{H}_2\text{O}$. Its composition is, sulphur trioxide, 32.5%; magnesia, 16.3%; water, 51.2%. It occurs in nearly all percolating ground waters and gives the water permanent hardness. Where a large amount of evaporation takes place, it is usually deposited in thick crusts or as delicate fibers. Massive epsomite is found at Leopoldshall, Stassfurt, associated with carnallite. In various limestone caves in Kentucky, Indiana and Tennessee it occurs in small crystals and in loose masses resembling snowballs. The most common occurrence of those mentioned is as crusts on cliffs; in mine workings; and various other places where sulphides may easily be oxidized to sulphuric acid which in turn acts on any magnesium minerals present.

The occurrence of epsomite in stalactites is very unusual, and, with the exception of the two stalactites shown, and a few small ones from three to four centimeters long, nearly all of the epsomite at this place in the Homestake Open Cut occurred in a thick white crust. In appearance the epsomite stalacties resembles gypsum to a marked extent, having a vitreous to greasy luster, and a crinkled, twisted and etched structure which is very common in a great deal of the crystallized gypsum of the Black Hills.

The largest stalactite which was found is shown in figure 2. It is 19 centimeters long, $1\frac{1}{2}$ centimeters wide at the bottom.

5½ centimeters at the widest part of the top, and weighs 103 grams. At A, Fig. 2, there is a hollow cylinder of epsomite in which there are three very small but well formed prismatic, orthorhombic crystals of epsomite. Included within these small



STALACATITES OF EPOMITE FROM THE BLACK HILLS.

crystals, near the terminations, are several minute bubbles. About three centimeters of the lower end of the stalactite is hollow and is also lined with small prismatic crystals of epsomite.

The stalactite shown in figure 1 is the second largest one that was found. It is 7½ centimeters long, from 1½ centi-

meters to 2 centimeters in various widths and weighs 31½ grams.

When kept in a dry atmosphere, epsomite gives up its water of crystallization and then has the appearance of a white enamel.

While making an examination of the N. Pope Mine at Keystone, South Dakota, Dr. F. W. Traphagen, Professor of Metallurgy at the South Dakota State School of Mines, found a mineral occurring as very delicate fibers from a half to one inch long. This mineral was identified as epsomite by J. P. Connolly, Professor of Geology and Mineralogy, of the same institution.

Epsomite can now be added to the long list of minerals occurring in the Black Hills of South Dakota.

“Research and Social Evolution” by C. F. Hirshfield, in the February number of *Mechanical Engineering*, brings out many interesting pointers connected with the engineering field. Research, according to the author, is the search for facts and industrial research is the search for industrial facts. This, he points out, opens a broad and unlimited field for the research worker. The value of research lies in substituting methods of assurance, based on facts, for those of guess, which, in the past, have been the bases of judgments made by industrial leaders. Nor is the author pleading alone for what he terms material research, but for economic research as well, and most particularly for sociological research, believing that our basic knowledge and control of human relations have not kept abreast of social evolution.

Following this article is another on the same subject entitled “Research and Industrial Wastes,” by George S. Hessenbruch, president, Industrial Engineers’ Corporation. He makes a strong plea for research on the subject of industrial wastes and closes his paper by describing a research laboratory now contemplated for pursuing this type of investigation.

A new process for making high speed steel without the introduction of tungsten, molybdenum, cobalt or vanadium as an alloy, has been developed and patented in England.

AMERICAN ASSOCIATION OF ENGINEERS.

By HUSTON SCHRADER.

In the February issue of the *Pahasapa Quarterly* mention was made of the fact that a branch of the American Association of Engineers had been organized at the School of Mines. The value of a club or chapter of this nature to the students of any engineering school is unlimited. The objects, aims, present and future standing of the American Association of Engineers in the engineering world are only a few reasons why the forming of chapters in every engineering school in the country should be encouraged.

Through co-operation with National Headquarters and the Dakota Chapter at Pierre a club has been organized here to further this work amongst the students. Meetings are held every week and topics relating to modern engineering are brought up for discussion. Two members give special talks prepared with the idea of giving the members an insight into practical problems which may be encountered when launching into their chosen field. In this sense we have been especially fortunate in having members who have put in their vacations on some of the big projects of the States, United States and Europe during the World War.

Speakers have been secured for April and May who will present subjects pertaining to contracting and electrical power; men who know these subjects from beginning to end.

During the past month Doctor Bisson presented the topic of Entropy to the A. A. E. and guests. The subject is a large one and the way it was handled by a man who knows was surely an inspiration to all in attendance.

The club is open at all times to suggestions as it is the object and aim to make it one of the big things at the School of Mines in future years. President Luther M. White, C. E., '20, has taken hold with a snap and vigor which can mean nothing but success for the club this year, with a firm footing to start the new year with. The club would like to hear from other clubs interested in this work over the country. Direct correspondence to Mr. William M. Aikman, Secretary, A. A. E., care of the South Dakota School of Mines, Rapid City, South Dakota.



Alfred Alder, '13, is mill superintendent for the Nevada Packard Mines Company, Lower Rochester, Nevada.

Samuel C. Dickey, '12, is consulting engineer and manager for the First National Mining Company, which has properties in Creede, Colorado, and Hill City, South Dakota. His address is at the former place.

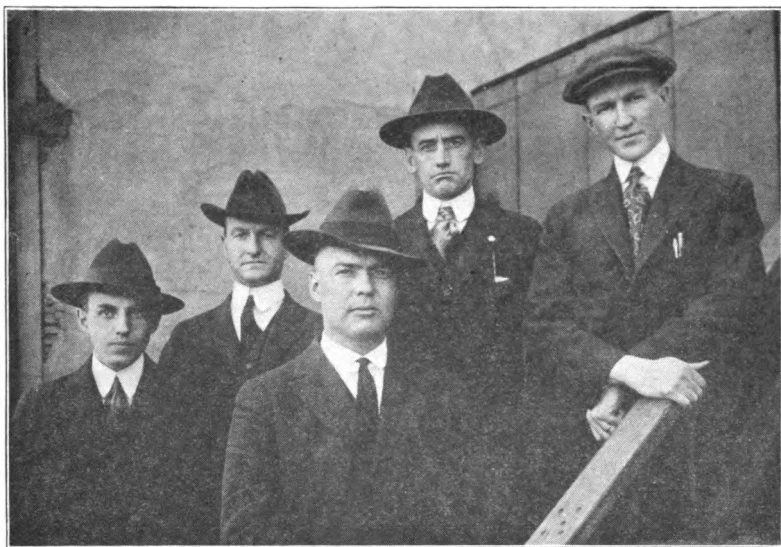
L. S. Overpeck, '08, though in the livestock commission business with Frazier and Johnson Commission Company of South Omaha, Nebraska, still retains an interest in mining and School of Mines work as evidenced by his subscription to the *Pahasapa Quarterly*. He also writes that J. Q. Betterton, '09, has accepted a position with a British company as metallurgist to do work on complex lead and zinc ores, the mines of which are located in Rhodesia, South Africa. Mr. Betterton left for London during the first part of March. He was formerly with the American Smelting and Refining Company at Omaha, Nebraska.

The last issue of the *Pahasapa Quarterly* gave H. W. Mara's address as Nelson, Arizona. However this should have been Techatticup Mine, Nelson, Nevada.

Also, Hugh M. Henton desires that we correct the statements made in the last issue in which he was given the title of professor. He is, instead, Instructor in Metallography and Metallurgy. At the Case School of Applied Science the title of professor belongs to the head of the department. Professor Charles H. Fulton holds that position.

G. Howell Clevenger, '01, has recently been elected a director of the American Institute of Mining and Metallurgical Engineers.

State School of Mines graduates, who have made good at the Omaha plant of the American Smelting and Refining Company, and who, as technical men, were largely responsible for the magnificent output of this plant during the war to the amount of approximately fifty million dollars annually.



From left to right: Virgil T. Price, chemist; Eli H. Hvistendahl, chemist in charge of chemical laboratory; Jesse O. Betterton, chief experimental chemist; Arthur E. Hall, general superintendent; B. Marvel O'Harra, superintendent of the bismuth department.

Mr. Betterton, after ten years of almost continuous connection with the company, recently resigned in order to become chief metallurgist for the Rhodesia Broken Hill Development Company, Broken Hill, Rhodesia, Africa.

Mr. Hall is to be with us for a brief time early in May and will give several lectures to the students in Metallurgy.

These men have all been doing a particularly high grade work and their friends at the School of Mines have good reason to be proud of them.

THE PAHASAPA QUARTERLY

SIoux INDIAN: "PAHA." HILLS "SAPA" BLACK

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INTERSCHLASTIC FIELD MEET.

The School of Mines in an endeavor to further the athletic activities of Western South Dakota is holding a Field and Track Meet at the school during the middle of May. Too much cannot be said regarding the benefits to be derived from such a meet. The bringing together of the representatives of the various high schools of this section of the country in a competitive way will serve as an incentive to each school to excel not merely in athletic lines, but in the scholastic abilities of its representatives as well. This meet will serve to unite the educational institutions in such a manner as to be mutually beneficial to all. Through each school's representatives that institution will be known so it is highly desirable that all send their best not merely as athletes but as true representatives of the ideals and standard of the school which they represent.

The School of Mines has gone to considerable expense to make this meet possible. Besides providing the necessary track, the contesting athletes will be the guests of the School and no efforts are being spared to make their visit enjoyable—one which will be long remembered in the years to come. Through the personal efforts of Mr. Fred Gushurst, assisted by the faculty and several committees of students, the meet is bound to be a

success. A complete program has been outlined. medals of an appropriate design have been ordered, a souvenir program will be printed and a number of entertainments have been provided.

With the above as a start, and with the co-operation of the high schools, the meet will be an undoubted success. We can look forward to the coming years when this meet will be the classic event of the season. In those future years other things may be added which will give those students interested in other lines besides athletics an opportunity to pit their ability against the similar abilities of students of other schools. With the above in view, the School of Mines cordially invites the High Schools of Western South Dakota to participate in this scholastic meet.

STUDENTS' ASSOCIATION ELECTION.

On Wednesday, May 5th, the Sophomore, Junior and Senior Classes of the coming year will be called upon to each elect a member to the Executive Committee of the Students' Association. The executive committee in turn elects the President, Vice-President, Secretary and Treasurer of the Association.

The latter officer is a faculty member. The other three are students. These students have the full control of all student activities. It is incumbent upon them to supervise and control all non-academic activities of the student body as a whole. They have in their hands your college life. Such being the case, it evolves upon the students themselves to consider seriously who are to be their representatives.

The last number of the Pahasapa Quarterly of this year will be a scenic number presenting several articles relative to the beauty of the Black Hills and Badlands, besides giving much interesting information concerning this region. An article on the caves in the Black Hills written in collaboration by J. Harlan Johnson and John P. Snyder, illustrated by many new pictures, is one of the many features of this issue.

Other articles on the Badlands, Limestone Country, Forests and Hunting and Fishing will also appear. School material will be abundant in that the scholastic track meet and commencement exercises will have a place of prominence.

LIBRARY NOTES.

By DELLA M. HAFT.

The Library has always subscribed for an excellent list of periodicals which will be increased this year by the addition of American Legion, The Americas, Botanical Abstracts, Engineering and Contracting, Good Roads, La France, Library Journal, Mechanical Engineering and Municipal Engineering. The following newspapers, besides those on the regular list, have also been subscribed for: New York Times, Manchester Guardian, La Prensa and La Patrie.

New books are arriving. Give yourself the pleasure of looking them over and planning your reading for leisure hours.

The Library recently has purchased the Industrial Arts Index from 1913 to the current number. It is to the technical journals what the Reader's Guide is to the general magazine. About one hundred technical periodicals are indexed. As monthly publications precede the annual accumulations, it keeps you in touch with the latest articles.

Twenty-four volumes of Americana have arrived and the others will follow as soon as published. The encyclopedia emphasizes scientific articles and its recent revision by leading scientists of the country, makes it a valuable contribution to our scientific subject matter.

Are you 100 per cent. efficient? See what the library has on the subject of efficiency.

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Library of Congress cards are being used to catalog the new books. Let the card catalog help you in finding what you want. The librarian will gladly explain any points in regard to its use.



By HUSTON SCHRADER, '21.

By a score of 21 to 15, the Miners defeated Chadron Normal on the night of March 6th. This game, one of the few played on the home floor, did not show the team work of either five as it should have done. However, in spite of adverse conditions, the Miners showed that with equal opportunities for effective practice they could hold the best teams to low scores. This game was the sixteenth of the season in which the Miners had participated; of the total number nine ended as victories for the Engineers.

The season of 1920 closed with a final game with the Belle Fourche American Legion team. Here again the Miners brought home a victory to their credit.

In summing up the season's efforts a few words of encouragement for the future will suffice.. In spite of the fact that they lacked a gymnasium of their own, which of a necessity interfered to a large extent with the team's highest efficiency, the Miners came through the season with a record not to their discredit, but with the promise of a future in basket ball history. Due to the untiring efforts of Coach Gushurst they surmounted to a great extent many of the disadvantages that might have discouraged this form of athletics. The season goes down in the history of the school as the dawn to a victorious future.

The following men, due to their efforts, will receive their letters Stewart, Primrose, Gantz, Friday, Shedd, Lund and Grey.

BASEBALL.

The ending of the basketball season does not see the close of activities in athletics. Baseball, track and tennis promise both variety and excitement. All require effort and perseverance. With this thought in mind there is no reason why the Mines

should not play an active part in these sports. The material is very much in evidence as shown by the interest taken of late in the interclass indoor baseball games.

TENNIS.

With the coming of warmer weather tennis again is being talked about. Although nothing definite has been heard, the nets probably will adorn the gumbo courts this season and the faculty and janitors will again battle for the boiler house championship.

TRACK.

Of paramount importance for the coming season is the track meet to be held here during the middle of May. The equipment is already here and the grounds soon will be thrown into shape for the coming events. Although an interhigh meet, many of the students here have taken the opportunity to attain proficiency in some of the field events. The coming months will see a revival of interest in all these sports which will work to the best interests of all.

THE FIRST ANNUAL BLACK HILLS FIELD MEET.

By FRED GUSHURST, Athletic Director.

General preparations for the athletic event of the year, the First Annual Black Hills Field Meet were put under way at a recent meeting of the board of control of the Students' Association. The date for the meet was definitely set for May 14th. The cups to be awarded the winners of each relay and the team securing the greatest number of points at the meet were selected. For the medals to be given the successful contestants in each event an original, appropriate design submitted by William Aikman was adopted. A committee was selected to get up an elaborate program which will contain the order of events, the names of the contestants and the school they represent. It will contain several interesting cuts and will be a very good souvenir of the meet.

Other committees were chosen to assure the success of the following program:

Thursday evening, May 13th, 7:30 p. m. to 9:00 p. m.—

Entertainment at the Elks' Theatre for the visiting teams.

Friday, May 14th. At the School of Mines—

General assembly of contestants—9:30 a. m.

Order of events:

100-yard dash, trials, 10:00 a. m.

100-yard dash—semi-finals.

120-yard high hurdles—trials.

120-yard high hurdles—semi-finals.

One-mile run.

440-yard run.

A novelty by School of Mines students.

100-yard dash—finals.

120-yard high hurdles—finals.

One-half-mile relay.

Dinner—12:30 p. m.

220-yard dash—trials.

220-yard dash—finals.

A novelty by School of Mines students.

220-yard low hurdles—trials.

220-yard low hurdles—semi finals.

880-yard run.

Pole vault.

Shot put.

220-yard low hurdles—finals.

A novelty by School of Mines students.

Running high jump.

Running broad jump.

Discus throw.

One-mile relay.

Supper—5:30.

Awarding of medals and cups—6:00.

Entertainment and dance at Auditorium—7:30 p. m.

The meet will be open to all High Schools in South Dakota west of the river. To assure the eligibility of the contestants and to provide that the names of all the entries from the different schools may appear on the program, and to arrange for

their comfort, the request is made that the schools send in the names of their contestants to F. W. Gushurst, Athletic Director, of the School of Mines, by May 1st.

Each school will be permitted to enter but two men in each event, although they may send in the names of three, and they may enter as few or as many events as they desire. It is planned that the first point winner in each event will be sent by his respective school to the State meet to be held at Brookings on May 21st.

Every school west of the river is cordially invited to send a team and during their stay in Rapid City will be the guests of the South Dakota School of Mines.



RIGHT!

The teacher was giving the class a natural history lecture on Australia.

"There is one animal," she said, "none of you have mentioned. It does not stand up on its legs all the time. It does not walk like other animals, but takes funny little skips. What is it?"

And the class yelled with one voice, "Charlie Chaplin."

THE MOTHER INVESTIGATED.

"Mother, is father in the fruit business?"

"No, dear. What put that idea in your head?"

"Well, pa took me for a walk Sunday and met Mr. Parsons, and all they talked about was peaches, pippins and dates."

"THE MINES' DORMITORY"

By JOHN PHILIP SNYDER.

As the first beam of the morning sun cast its fiery glow over the plains to the immediate east of Rapid City, exciting stories of a spectacular fire were circulating amidst the awakened townspeople. A calamity had happened during the night, namely the total destruction of one of Rapid City's old landmarks, the Park Hotel, resulting in eleven families, including some twenty-five children, being rendered homeless.

The above incident sums up in brief the fate of the building once used as a dormitory by the School of Mines. Away back in 1902-03 the students of the School of Mines would meet within its walls for mutual counsel. Behind its walls the war plans of the successive Sophomore classes were designed from year to year, and it was within this court of justice that the fate of many a freshman was decided.

But now, alas, nothing is left of that stately memorial, save a conglomerate mass of smoldering ruins.

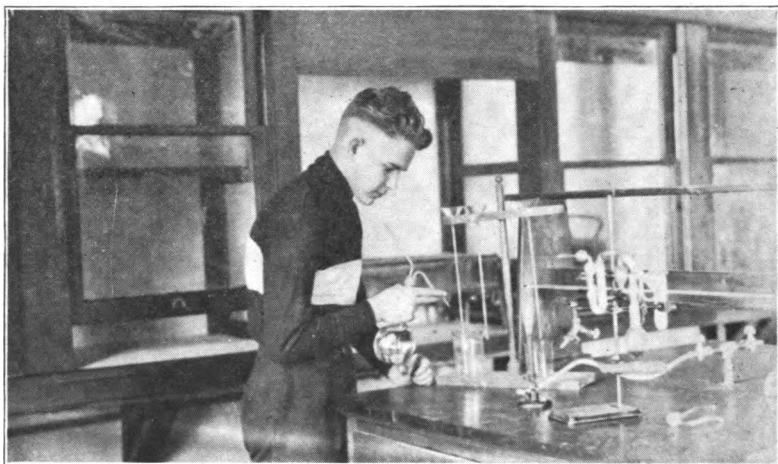
To the present students at the school, this incident had no special significance, but to the old grad this news will bring numerous recollections of their college days, of their conspiracies and their battles, of their victories and their defeats. These incidents will pass in silent procession before their eyes and will once again awaken within their hearts their old time school spirit and their strong love for their alma mater which they so earnestly acquired while living in the "Dorm."

That school spirit and love of alma mater which is inculcated into every college student is but a forerunner of their future love of country and spirit of true democracy which should be possessed by every loyal American citizen. This training in democratic spirit which a college dormitory automatically imparts to its residents is of equal importance to the technical training in the making of a good engineer and college graduate.

At the present writing the School of Mines is, unfortunately, without a college dormitory. The men are housed in various parts of the city. The school has developed to such proportions that a dormitory is not only urgently needed but of the most

vital importance to the future growth of the institution. That such an addition to the School of Mines is not only a possibility but a certainty is due to our ever progressing President, who, due to his firm belief in the progress of the institution, has already placed the matter before the proper authorities, and tradition tells us that whatever Prexy O'Harra goes after, he gets.

So, we may eagerly look forward to the near future when side by side with our new \$100,000 engineering building will be our new \$100,000 Dormitory, where, once more the almighty Sophs may draw their plans, while in the adjoining room the doomed Freshmen await the verdict, where the conscientious Juniors may once again "plug" for that test in Mechanics, where the stately Senior may trim his newly acquired mustache, and where the old Grad may visit the social room and view with delight the penants and trophies which adorn the walls to remind him of those good old days at the School of Mines.



IN THE QUANTITATIVE LABRATORY

DRILL AND CRUCIBLE CLUB.

By A. I. JOHNSON, '22.

Program, February 12th:

Placer MiningGardner Gantz

Mining at Keystone.....Mark Lintz

Mr. Gantz in a general way outlined the various methods in the most important placer mining districts of the world. The informal way in which he handled the subject and its various details made the subject especially interesting to all .

Mr. Lintz because of his personal experience around Keystone was well able to handle his subject. His presentation of the topic from an unusual angle, with frequent insertion of anecdotes of the early days, gave his audience a good understanding of what that camp has undergone when Keystone was on the mining map.

Program, February 26th:

Flotation in Eastern region....S. McKirahan

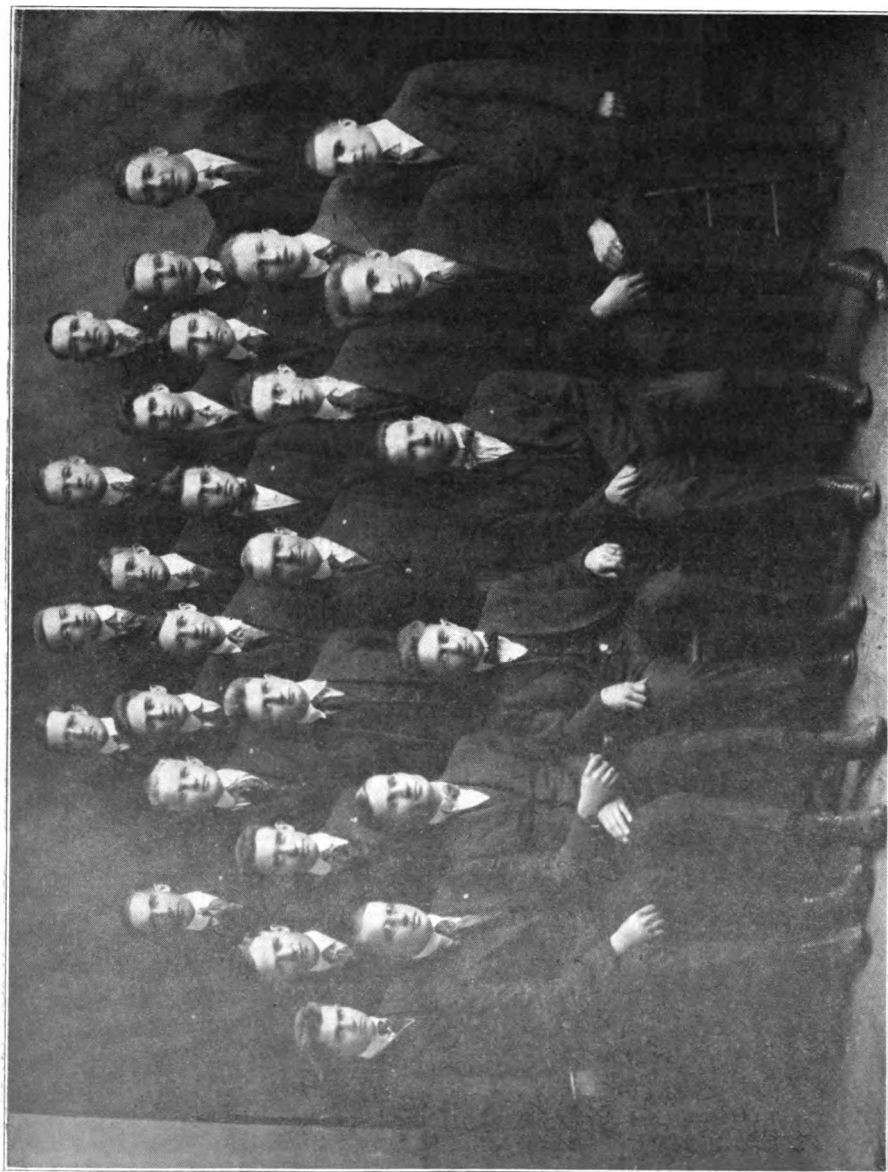
Crystal CaveJ. H. Johnson

ColumbiteW. A. Waldschmidt

Mr. McKirahan's subject was presented in a clear and concise way. His consideration of his topic was especially valuable because of his ripe knowledge of the process drawn from a close observation and contact with the flotation operations.

Mr. Johnson's subject, "Crystal Cave," has been the object of his observation and study during the past year. For the reason that we do not find a large amount of material relative to the cave, his portrayal was interesting and of general value.

Mr. Waldschmidt having in his possession some of the best specimens of Columbite known, described their features of gen-



DRILL AND CRUCIBLE CLUB.

Top Row—J. H. Johnson, Bowen, O. Johnson, G. Wurtsbaugh; Second Row—E. Hoffman, M. Jacobs, F. Elliott, G. McCracken, A. I. Johnson; Third Row—G. Johnson, J. Snyder, F. Calhoun, C. Platt, M. Lintz; Fourth Row—Wagner, Schuler, J. Hayes, G. Gantz, G. Richardson, E. J. Markvart, Primrose, R. Moore; Bottom Row—R. March, M. Parsons, W. Waldschmidt, G. Enos, M. Hett.

eral interest, completing this with a general review of Columbite.

Program, March 11th:

Process of Manufacture of Wrought Iron
PipeDr. Traphagen

Quantitative Analysis of Tungsten
..... George Enos

Dr. Traphagen, illustrating his subject by slides, gave a very clear description of the process of manufacture of "Wrought Iron Pipe."

Mr. Enos for the past few months has been making special analyses of Tungsten ores. In his consideration of the subject he gave the society the benefit of his recent investigations.

BUDDIES.

"Do you know my brother?"

"Yes. We sleep in the same pew at church."

A MIXED PRAYER.

Tommy had been playing 'till he was very tired, and did not feel inclined to say his prayers, but his mother insisted. So Tommy began:

"Now I lay me down to sleep,

"I pray the Lord my soul to keep,"

"If," prompted the mother.

Tommy sleepily:

"If he hollers, let him go

"Eney, meeny, miny, mo."

"George," said the Titian-haired school marm, "is there any connection between the animal kingdom and the vegetable kingdom?"

"Yeth, ma'am," answered George promptly, "Hash."

It may have been George's sister, Nellie, who, when asked how to make a Maltese cross, replied, "Step on its tail."

LOCALS.

By EDGAR R. HOFFMAN.

Chief C. Y. Robe, of the Rapid City Indian School, visited the School of Mines recently and entertained the faculty and students with an interesting account of the Wounded Knee Battle. This fight, he said, should more properly be called the Wounded Knee Massacre. His talk was not merely entertaining but historically instructive as well. Mr. Robe is an excellent speaker and won the sympathy and respect of his audience, for a people now developing toward what is termed civilization.

Elden Gamble and Huston Duncan left recently after losing a number of weeks of school while under quarantine for scarlet fever. We were sorry to see these men go but hope to have them with us again next year.

Four new students enrolled for the second semesters work. They are: Leon Kalb, Lester Olson, Everett Dickenson, and Lester Philips. Mr. Kalb, who was a former student, has just returned from South America.

Frank Cremer, '17, visited the college recently. He is at present employed as an engineer in the South Dakota State Highway Commission at Pierre.

W. H. Willesen, a special student, will soon leave for the Utah College of Agriculture, where he will continue his course in concrete road construction. Mr. Willesen was severely injured while serving in the army, and therefore is entitled to the aid and privileges given him by the Federal Board of Vocational Education, which is sending him to the above named college.

J. Harlan Johnson, who has finished the required amount of work for a B. S. degree in mining, has left for his home in Philadelphia. He will return for commencement.

PERSONALS.

By "DINTY" MOORE, '22.

After dancing 86 dances the only thing that "Swede" Wille-
sen was able to do creditably was yell. Consequently he has se-
cured a position as "Balyhoo Man" for the Novak Show.

Editorial Note:—The way to die rich is to make a lot of
money and keep away from chorus girls.

IN GEOLOGY CLASS.

Dr. O'Harra—"What are the picks worth?"

Prof. Connolly—"I don't know what they are worth but
they are charging \$2.75 for them."

Perseverance availeth a man much. Repeated renewals of
the sign on the bulletin board brought "Prep" Christmas.

We understand that Mr. Friday will soon present for pub-
lication a paper on "The Care of Cats and Kittens." The author
is at the present time carrying on an interesting experiment
along this line, and we do not doubt but what his article will
contain many valuable pointers relative to this subject.

A. I. Johnson has secured the first four letters of the
alphabet on his report card. By a huge effort he may obtain the
remaining twenty-two before graduation. In that case he would
have at least the alphabet well learned.

Platt's fame as an assayer has spread to such an extent that
visitors, usually of the fair sex, often ask to see him. The ad-
visability of ordering a glass case, placing it in the museum,
and setting him therein, is being considered.

The cow-puncher at Wasta who traded his chaps for six
dances with one of the "Forty-niners" hasn't much on Hoffman,
who exchanged a pair of new rubbers for three whirls with
"Billy."



The weaker sex is that portion of the human race which goes down town in zero weather in a half-masted lace waist and pumps to buy a muffler and woolen socks for her husband so he can go to work.

Speaking of a bird in the bag being worth two in the bush, our favorite telephone operator says a ring on the finger is worth two on the phone.

Sign says: "Ladies'-Ready-to-Wear-Clothing." Well its about time.

SLIGHT MISTAKE.

A young lady from the city on making her first visit to the country was very much amused by some calves running across the pasture and exclaimed, "Oh, what pretty cowlets!"

"Yes, miss," drawled the farmer, "they are pretty, but them's bullets."

HERE'S A GOOD ONE—DEA' ME!

"Why is a kiss over a telephone like a straw hat?"

"Well?"

"Because it isn't FELT."

A blacksmith applying for work was asked if he was a fast workman.

"Yes, sir," he replied, "the last place at which I worked we shoed the horses on the trot."

He—"Are you fond of indoor sports?"

She—"Yes, if they know when to go home."

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